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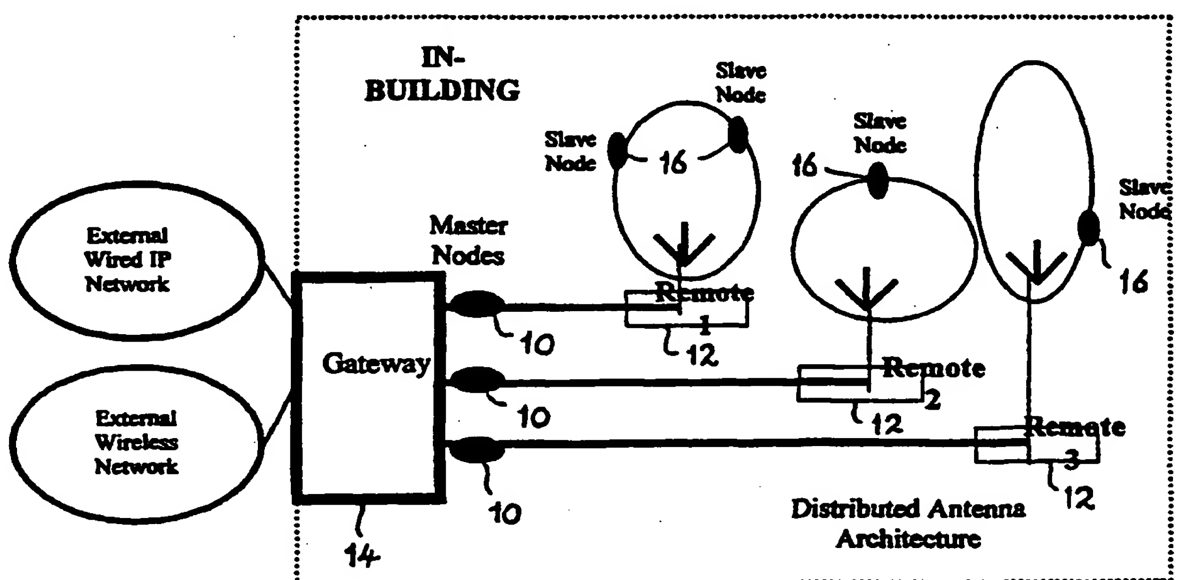

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(57) Abstract: A gateway system for interconnecting wireless ad-hoc netwoks to achieve the functions of a wireless local area network (LAN) using a distributed antenna architeture is described. Multiple master nodes (10) are connected to respective multiple remotes (12) of a distributed antenna architecture connected to a gateway (14). It is also possible for a master node to connect to multple remotes, or for multiple master nodes to connect to one remote. Each master node (10) is configured to form a piconet with one or more slave nodes (16). The slave nodes may take the form of any suitable mobile or stationary device fitted with a transmitter, receiver and antenna, such as computing devices, desktops, notebooks, fax machines, printers, mobile phones, cameras, headsets and personal organisers.

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A GATEWAY SYSTEM FOR INTERCONNECTING WIRELESS AD-HOC NETWORKS

FIELD OF THE INVENTION

The invention is in the field of wireless communications and networking. It relates to a protocol, algorithm, method, architecture and technique for interconnecting wireless ad-hoc networks to achieve the functions of a wireless local area network (LAN) using a gateway and a distributed antenna architecture. It has applications in the areas of wireless networking and communications for computing devices, desktop computers, notebook computers, fax machines, printers, cameras, headsets, mobile phones and personal organisers.

BACKGROUND TO THE INVENTION

An ad-hoc network is formed by a group of mobile nodes when these mobile nodes are within certain range of each other. The mobile nodes are equipped with transmitters, receivers, and antennas. The range is based on the transmitter power, the receiver sensitivity, the local propagation environment, and the interference condition of the nodes. Mobile nodes can join or leave the ad-hoc network at will. Since the interconnection among the mobile nodes is formed in an ad-hoc fashion, there is no fixed topology among nodes and the link connectivity is dynamic.

One of the major advantages of using an ad-hoc network is that the cost of the wireless device on a mobile node is usually very low. This invention takes advantage of the benefits of wireless ad-hoc networks (such as cheap wireless devices and the capability of forming a network) and implements a wireless local area network (wireless LAN) by interconnecting wireless ad-hoc networks utilising a gateway and a distributed antenna architecture. It also eliminates one of the disadvantages of ad-hoc networks, ie, two nodes can still communicate with each other although they are not in range since a centralised master node can relay the message from one node to another node via a distributed antenna architecture. The resultant wireless LAN is implemented at significantly lower cost than relatively more complicated wireless

LANs, such as the Institute of Electrical and Electronics Engineers (IEEE) 802.11, since low cost ad-hoc devices make a cheaper overall network.

A number of prior art systems have been developed for improving the interconnectivity of mobile devices in wireless ad-hoc networks.

US Patent No. 5623495 (Portable base station architecture for an AD-HOC ATM LAN) describes a system that employs an asynchronous transfer mode (ATM) switch to interconnect multiple portable base stations. The mobiles within the coverage of a portable base station can communicate with other mobiles in the coverage of the same or different portable base stations. US 5623495 distinguishes a base station (BS) from a mobile. The present invention does not have the concept of a BS. It typically uses a master node of an ad-hoc network which is no different from a slave node. The present invention uses a distributed antenna technique to interconnect the piconets formed by different master nodes.

WO 99/11081 (An apparatus and method for peer-to-peer link monitoring of a wireless network with centralised control) describes a system in which the quality of service (QOS) of the links is monitored by all stations that have access to the links. The link with the best quality is selected as the centralised controller. The system chooses the centralised controller based on the QOS reported from the stations. In the present invention, the master node is typically pre-chosen and is connected to one or more of the remotes of the distributed antenna architecture. In WO 99/11081 any station can become a centralised controller, whereas in the present invention, a slave node cannot become a master node and vice versa.

TDK recently announced on the World Wide Web (WWW) that it will introduce "bubble of connectivity" using Bluetooth technology to implement a personal area network. However, it is understood that the bubble is used to connect a Bluetooth-enabled computing device to a phone, a printer or a wired LAN. This idea still falls into the category of an ad-hoc network, not a wireless LAN.

SUMMARY OF THE INVENTION

Throughout this specification the term "comprising" is used inclusively, in the sense that there may be other features and/or steps included in the invention not expressly defined or comprehended in the features or steps subsequently defined or described. What such other features and/or steps may include will be apparent from the specification read as a whole.

According to one aspect of the present intention there is provided a gateway system for interconnecting wireless ad-hoc networks to a variety of external wired IP networks and/or external wireless networks as wireless local area networks (LANs), the gateway system comprising:

a gateway connected to one or more remotes of a distributed antenna architecture;

a master node connected to the gateway and configured to form a piconet with one or more slave nodes via the remotes, said master node being used to determine the synchronisation aspects of the piconet, and wherein the gateway routes the connections with the one or more remotes in an optimal manner within the same piconet or from one piconet to another.

Typically the gateway is connected to the remotes by a wireless connection. Alternatively, the gateway is connected to the remotes by a wired connection.

Typically the gateway system comprises a plurality of master nodes, each master node being used to form a piconet. One difference between an ad-hoc network and a piconet is that the former does not have a fixed master node location for the network, but the latter does. The other difference is in an ad-hoc network, any node is allowed to communicate with other nodes. But in a piconet, the slave nodes are allowed to communicate directly with the master node only, not other slave nodes. The slave node can only communicate with other slave nodes in an indirect fashion, that is, through the master node. The master node determines the synchronisation aspects of the piconet (such as timing and frequencies).

Preferably the gateway dynamically switches operation modes for the master node by reconfiguring the connectivity of the remotes within the distributed antenna architecture based on the traffic load and QOS requirements. Advantageously the gateway performs protocol conversion from one piconet to another if required. The gateway may also perform traffic management (such as queuing disciplines and scheduling) for QOS provision of each connection.

Typically, one master node is connected to one remote of the distributed antenna architecture. That is to say one remote forms a piconet. However, it is also possible for a master node to connect to multiple remotes or multiple master nodes to connect to one remote.

According to another aspect of the present invention there is provided a method of interconnecting wireless ad-hoc networks to a variety of external wired IP networks and/or external wireless networks as wireless local area networks (LANs), the method comprising:

providing a gateway connected to one or more remotes of a distributed antenna architecture;

providing a master node connected to the gateway and configuring the master node to form a piconet with one or more slave nodes;

using the master node to determine the synchronisation aspects of the piconet; and,

using the gateway to route the connections in an optimal manner from one piconet to another.

According to a still further aspect of the present invention there is provided a gateway for interconnecting wireless ad-hoc networks as wireless local area networks (LANs), the gateway comprising:

a gateway controller adapted to communicate with a master node configured to form a piconet with one or more slave nodes, the master node being connected to one or more remotes of a distributed antenna architecture connected to the gateway, wherein said gateway controller can route the connections in an optimal manner from one piconet to another.

Preferably said gateway controller performs admission control, service provisioning, connection set-up and tear-down, routing of traffic, as well as roaming functions. Advantageously the gateway controller includes an optimisation unit for enhancing the performance of connections by optimising all protocol layers of the connections.

BRIEF DESCRIPTION OF THE DRAWINGS

In order to facilitate a better understanding of the nature of the invention, the preferred embodiments of the gateway system and method will now be described in detail, by way of example only, with reference to the accompanying drawings, in which:

Figure 1 is a schematic diagram illustrating a first embodiment of the gateway system in accordance with the present invention;

Figure 2 illustrates schematically a second embodiment of the gateway system in accordance with the present invention;

Figure 3 illustrates a third embodiment of the gateway system in accordance with the present invention;

Figures 4a, 4b and 4c illustrate a third embodiment of the gateway system in accordance with the present invention;

Figure 5 is a functional block diagram for a preferred embodiment of a gateway in accordance with the present invention; and,

Figure 6 illustrates a fourth embodiment of the gateway system in accordance with the present invention

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

In the gateway system of the present invention a gateway communicates with master nodes via a distributed antenna architecture. Each master node is used to form a piconet. Each master node is typically equipped with a transmitter and receiver

containing RF, IF, and baseband (with physical and link layers) functions. The master node determines the synchronisation aspects of the piconet (such as timing and frequencies). Each piconet is typically identified by an ID unique to the master node. A master node is generally able to provide one or more services or applications (such as voice and Internet access).

Based on the service requested, the slave nodes attach themselves to the appropriate piconet. That is to say, a slave node can determine whether the piconet has the right service or not based on the service advertised by the master node. The slave nodes can take any form such as a desktop computer, mobile phone, notebook computer, camera, headset, personal organiser and so on. Each slave node is equipped with a transmitter, a receiver and an antenna. In order to join the piconet, the ID of the slave node needs to be passed onto the master node for connection establishment and authentication.

It is possible that the slave node also forms a piconet of its own. That is to say that the slave node acts as an independent master node in another piconet and this independent master node is not part of the gateway system. This hierarchy of operation is required to interconnect multiple personal area networks, where an independent master node system is used to control each personal area network. In this case, the independent master node acts as a slave node in the gateway system and is connected back to the gateway through a gateway master node.

When a master node receives a connection request message from an application of a slave node, the master node forwards this request to the gateway. The gateway uses information within the request to determine the type of connection. The gateway can also use the QOS needed (and other requirements in the request) to determine the amount of capacity required to be allocated to the slave node and the type of connection (packet-switched or circuit-switched) as part of service provisioning. If the destination is located within the same piconet, the routing will occur directly between the source slave node and the destination slave node.

If the destination is located in a different piconet, the gateway will coordinate the master node in each of the piconets such that the routing can be done from one

piconet to another piconet. In addition to the basic wireless LAN application, higher level applications such as intercom, cordless phone, user notification for incoming e-mail, and real-time resource sharing can also be supported under this scenario. The famous Star Trek scene of using a pin size communicator on the chest to communicate with each other inside the ship can be realised using the invention. If the destination is located in a different piconet using a different ad-hoc interface standard, in addition to the master nodes coordination, the gateway also performs protocol conversion and interworking functions to interconnect the piconets.

There are typically two possible implementations for the remotes of the distributed antenna architecture. In the first implementation master nodes and remotes communicate via radio frequency. In this case, an antenna is not needed for the master node since its function is provided by the distributed antenna. In the second implementation the master nodes are located in the remotes. In this case, an antenna is needed on the master node.

IMPLEMENTATION 1

In Figure 1 a first embodiment of the present invention according to the first implementation is illustrated in which multiple master nodes 10 are connected to respective multiple remotes 12 of a distributed antenna architecture connected to a gateway 14. Typically, one master node is connected to one remote of the distributed antenna. In this embodiment, each remote forms a piconet. There may be more than one antenna connected to the same remote. Each remote may be connected to the gateway 14 using a dedicated pathway or a shared pathway. It is also possible for a master node to connect to multiple remotes or for multiple master nodes to connect to one remote. Each master node 10 is configured to form a piconet with one or more slave nodes 16. The slave nodes 16 may take the form of any suitable mobile or stationary device fitted with a transmitter, receiver and antenna. The master nodes are typically stationary and take the form of a wireless device equipped with a transmitter and receiver. The gateway 14 and distributed antenna architecture are normally provided within a single building or geographical area such as a campus, to enable wireless ad-hoc networks formed by a group of mobile nodes to achieve the function of a wireless local area network (LAN).

The gateway 14 includes processing means for dynamically switching operational modes of the master nodes 10 by reconfiguring the connectivity of the remotes within the distributed antenna based on the traffic load and QOS requirements. The gateway 14 routes the connections in an optimal manner from one piconet to another. The gateway 14 performs protocol conversion from one piconet to another if required. In this arrangement the gateway 14 also performs traffic management (such as queuing disciplines and scheduling) for end-to-end QOS provision of each connection. The gateway performs the co-ordination and service provisioning to external wireless networks, on the wireless pathway between gateway and remotes (if any) and between remotes. The gateway dynamically adjusts the number of piconets serving one given area to meet the capacity requirement. The gateway also dynamically adjusts the number of ad-hoc devices in a piconet to meet the capacity and QOS requirement of each connection (via admission control).

When a master node is connected to multiple remotes, the same information is sent to multiple geographical areas. Therefore a master node can communicate with multiple disjoint piconets. This scenario is depicted in Figure 2. This system configuration is typically used when the traffic loading in the coverage area is low, hence, one master node 10 is sufficient to meet the capacity demand for the area. There are several applications for this system configuration. The first application is where the number of master nodes can be adjusted based on the overall traffic load. For example, when the aggregate traffic loading in multiple coverage areas is still smaller than the capacity of a piconet, one master node is sufficient to meet the capacity demand for these areas. Otherwise, more master nodes can be deployed. The second is to maintain the connectivity for voice communications. In other words, a piconet can be dedicated specifically for voice communications. By multicasting the signal of a master node to multiple remotes, the (voice) piconet extends its coverage throughout the whole coverage area (such as a building) such that seamless (softest) handoff is possible from the coverage of one remote to another one.

When multiple master nodes 10 are connected to one remote, multiple piconets are formed in the same coverage area. In this case, a user may connect to multiple piconets simultaneously (using multiple slave nodes) such that the user data can be demultiplexed into multiple streams for sending through multiple piconets. The result

is the user throughput is increased kN times, where $k < 1.0$ and N is the number of piconets. The gateway 14 performs interference resolution among the overlapping piconets such that interference among them is minimised. For example, the gateway 14 can perform a proper selection of the hopping sequences of different piconets such that the interference can be reduced. This scenario is depicted in Figure 3. Typically, this mode of operation is used to serve high-data-rate connections.

The gateway 14 can dynamically switch the operation modes (one master for one remote, one master for multiple remotes, or multiple masters for one remote) for each master node by reconfiguring the connectivity of the remotes within the distributed antenna architecture based on coverage connectivity (unicast, multicast, or broadcast), traffic load, change of propagation environment and QOS requirements. Examples for the change of propagation environment include change of layout in a building and/or adding new cubicles.

A possible implementation for the dynamic change of the operation modes is described below with reference to Figure 4. Multiple master nodes are pooled at the gateway. A dedicated path exists from each remote to the gateway. A non-blocking switch 18 is used to connect the master nodes and the remotes. The switch 18 configuration is changed by the gateway based on the operation modes of each master node.

One example is used to describe the operation of this implementation with reference to Figure 4a, b and c. Initially, master node 1 is connected to remotes 1 and 2, and master node 2 is connected to remote 3 (see Figure 4a). It is assumed that there are two types of services: voice and Internet access. All master nodes are capable of serving both voice and Internet access. It is further assumed that a slave node in piconet 1 initiates a voice communication with an external network. In this case, master node 1 is dedicated to voice communications, ie. it does not serve Internet access service any more. That is to say that master node 1 will advertise service for voice application only. The mode of operation for master node 1 is to multicast its signal to all piconets to support the handoff capability for voice (see Figure 4b). (Note that if user tracking or user location function is implemented, master node 1 only needs to send its signal to the piconet the user is currently in and the neighbours

of the piconet.) Next, it is assumed that a high-data-rate connection is initiated in piconet 3. In this case, master node 2 is also deployed to connect to remote 3 to support the high-data-rate request (see Figure 4c). Another example is that master node 1 connects to remotes 1 and 2 for Internet access applications. When the traffic load requirement increases, the piconet served by master node 1 is split into two piconets. One piconet is served by master node 1 through remote 1 and the other served by master node 2 through remote 2.

Either an omni-directional antenna, a directional antenna or an antenna array may be deployed on the remotes. When an antenna array is deployed on the remotes, the gateway can reconfigure the coverage of each remote to match the traffic pattern. The gateway, as an option, can also route the traffic of the piconet to external wireless networks such as, for example, Global System for Mobile Communications (GSM), American National Standards Institute/Telecommunications Industry Association/Electronic Industries Alliance-95 (ANSI/TIA/EIA-95) or Third Generation Partnership (3GPP) Wideband-CDMA. (This implicitly increases the revenue of the wireless operators since the piconet traffic goes through the wireless links of the operators). In this case, the gateway contains multiple mobile processors to communicate with external wireless networks. The mobile processor in the gateway can multiplex the piconet traffic into a multiplexed stream and sends the stream through the external wireless air connection. With such a multiplexing function, the number of mobile processors required in the gateway can be drastically reduced.

Note that although a user can also use a wireless phone as a modem to connect to the external network without using a preferred embodiment of the present invention, the preferred embodiment offers several advantages. One advantage is that the user can connect to the external network with a wireless ad-hoc device only, ie, without a phone. For example, a user with a headset can connect to a GSM network through the gateway without a GSM phone. GSM network billing is handled by the gateway system and recovered separately from the user. Or a user with a digital camera can transfer the image to the external network without a phone. A second advantage is that the distributed antenna architecture greatly enhances the coverage for the piconet; consequently the user can obtain access to the external wireless network via the

gateway with a better coverage reliability. A third advantage is that the preferred embodiment can provide connectivity to external wireless networks for phones with different wireless standards. For example, the gateway can connect users with GSM or IS-95 phones in the piconet to a 3G external wireless network.

The gateway 14 can also route the connections from piconets to wired IP networks, including Ethernet, or other wireless networks, such as local multipoint distribution system (LMDS), as shown in Figures 1 to 3.

A high-level functional block diagram for a preferred embodiment of the gateway 14 is shown in Figure 5.

The gateway 14 preferably includes a plurality of pathway interface modules 30 that are used to interface with various pathways connecting the gateway and remotes. For examples, an Ethernet module is required when the pathway is implemented using Ethernet. An IEEE 802.11 module is required when the pathway is implemented using wireless IEEE 802.11 standards. When the pathway is implemented using a wireless technique, interworking function is also required to relay the messages from piconet to wireless pathway and from wireless pathway to the gateway.

A gateway controller 32 is in charge of various control tasks as shown in Figure 5. From a traffic management viewpoint, it performs admission control 34, service provisioning 36, connection set-up and teardown 38, routing of traffic 40, as well as roaming 42. The admission control 34 adopted in the gateway, may be similar to that defined in ATM. For example, when a connection request is received by the gateway controller 32 from one of the slave nodes, the controller determines whether this request should be admitted or rejected based on the loading condition of piconets and the QOS requirement of the request when the connection is from one piconet to another piconet. If the connection is from one piconet to an external network, the controller needs to perform coordination among the external network and the piconets to examine whether there is enough resource to accommodate this request such that the QOS can be provided. Service provisioning is also performed at this stage to accommodate the QOS requirement of the request. For example, the capacity for a

remote can be increased by properly configuring the operation modes of the master node such that more piconets can be formed to accommodate the connection.

Once the request has been admitted, the controller 32 instructs a data transport bus 44 to route the traffic from one piconet to another piconet if it is an inter-piconet connection. It instructs the data transport bus 44 to route the traffic from one piconet to an external network if the connection is between a piconet and an external network. For inter-piconet connection, when the piconets use different standards, the gateway controller 32 also needs to perform an inter-working function 46 such that protocol can be converted between two different standards. Inter-working function needs to be invoked also for connections between a piconet and an external network.

A roaming function 42 is provided by the coordination of the gateway controller 32 and external wireless network. For example, when a cellular user walks into a building, the user phone will automatically switch to ad-hoc standards mode (assuming the user phone is dual or multi-mode phone). Once the gateway controller 32 detects the user is within the coverage, the gateway will pass the user location information back to the external wireless network such that all incoming calls can be forwarded to the user via the gateway. Mobile IP can also be deployed to provide roaming capability for IP applications.

A protocol optimisation unit 48 enhances the performance of connections by optimising all protocol layers of the connections. For example, the gateway performs interference resolution among multiple overlapping piconets such that their operation can be orthogonal or quasi-orthogonal. Another example is the methods proposed to improve the performance for wireless TCP can also be implemented in the gateway (and/or the BS of the external wireless network). A radio link control (RLC) protocol can also be enhanced and implemented in the gateway (and/or the BS of the external wireless network). Another optimisation aspect is the saving of resources when multiple logical connections can be multiplexed into one physical connection. Specifically, when multiple slave nodes are communicating with an external wireless network, multiple logical connections can be formed between the slave nodes and the external wireless network. The protocol optimisation unit 48 ensures that these local connections can be multiplexed into one physical connection between the gateway

and the external wireless network. The end result is the saving of hardware resources at the gateway (such as mobile chip sets) as well as the air resource for the external wireless network. When communicating with an external network, IP address or directory mapping 50 also needs to performed by the gateway controller 32.

Compression, another task of the protocol optimisation unit 48, can be activated between the external wireless network and the gateway as well as between the remote and ad-hoc user device (slave nodes) to increase the overall spectral efficiency.

When communicating with an external network, IP address or directory mapping, firewall, mailserver DNS and other Internet services need to be performed by the gateway controller 32 as well.

A plurality of multi-mode interface modules 52 are used to interface a variety of external networks. When the external network is a wireless network, the multi-mode interface modules 52 act as mobile processors. Since multiplexing and compression can be done at the gateway (via the optimisation protocol unit 48), the number of mobile processors required to interface with the external network is largely reduced.

Billing can be done in a one step or a two step process:

In the one step approach, an external billable slave node (e.g. a mobile phone) has a virtual image registered to the external cellular network (as described above in relation to Roaming). When a call connection (incoming or outgoing) is to be established, the gateway system allows conventional call setup, negotiation and billing authentication to occur before the parties are connected. In this manner the gateway system takes no part in the billing cycle, and the user is billed directly to his mobile phone account.

Billing in a two-step approach:. In step 1, the airtime charge from the external wireless network will be billed to the owner of the gateway. In step 2, the gateway further bills its client based on traffic volume through the gateway to the external wireless network. This can be done at the time by debiting stored value cards (along the lines of a payphone card), or by other conventional billing means. There is a one-

to-one correspondence between the client and the slave node ID. When a mobile phone leaves the ad-hoc network, the gateway system removes the virtual image of it from the external wireless network interface.

An authentication process can be performed between the master node and slave node when the slave node intends to join the piconet or it can be done between the application server and the application client. For the application authentication, the gateway passes the authentication messages between the server and the client transparently.

Encryption is done at the service/application level or link level. For link-level encryption, the gateway may have to terminate the encryption and reintroduce another encryption if two slave nodes are using two different standards or if a slave node makes a request to communicate with an external network. For example, if the slave node is located inside a building using the wireless ad-hoc standards. The destination for the connection is located in the external wireless network.

One possible implementation for the internal transport mechanism (the data transport bus in Figure 5) for the gateway could be ATM adaptation layer 2 (AAL2)/ATM or Internet Protocol (IP.)

IMPLEMENTATION 2

The operation of implementation 2 (Figure 6) is similar to that of implementation 1 and is the preferred implementation. The main difference is that instead of pooling master nodes at the gateway, the remote itself contains a master node or a "cluster" of master nodes (with each master node controlling a separate piconet), a pathway transceiver and a LAN controller. Each remote contains a broadbeam antenna for communications to slave nodes within a piconet.

Each remote is connected to the gateway via a pathway thus allowing each piconet to partake in the gateway system. Each pathway couples the respective piconets back to the gateway either directly or, where it is beneficial to extend range or equalise traffic, by relay through other remotes. Each pathway is preferably implemented as a wireless connection, but may be implemented as a wired connection or a mixture of

the two. When a wireless pathway is implemented, each remote has at least one pathway antenna that could be a highly directional device. Directional antennae improve performance and reduce interference but are more complicated to set up. In some wireless pathway installations the same frequency band as the piconet can be used for the pathway. In other situations, use of the same frequency band may cause too much piconet to pathway interference, and in these situations an alternative band could be used for the pathway.

The number of master nodes active at a time in a cluster depends on the coverage connectivity (unicast, multicast, or broadcast), traffic load, change of propagation environment and QOS requirements as slave nodes are free to enter, leave and request services in an ad-hoc fashion. A cluster of master nodes within the remote is responsible for informing the gateway of the status of all slave devices within its respective piconets, the connections between them and the services requested by them. The dimensioning for the remote is done by it based on its operational mode (determined by the gateway) and local traffic conditions.

When the coverage of two or more remotes 12 overlap, loading sharing or handoff can be implemented among remotes. For softest handoff, multiple adjacent remotes must be coordinated such that the user in effect sees only one piconet from these remotes. For soft handoff, the user needs to establish an additional link with adjacent remotes first before the original link is torn down.

Similar to Implementation 1, when multiple master nodes 10 are located in one remote, multiple piconets are formed in the same coverage area. In this case, a user may connect to multiple piconets simultaneously (using multiple slave nodes) such that the user data can be demultiplexed into multiple streams for sending through multiple piconets. The result is the user throughput is increased kN times, where $k < 1.0$ and N is the number of piconets. The gateway system performs interference resolution among the overlapping piconets such that interference among them is minimised.

The gateway 14 is the central point of control for the gateway system. It provides system wide management, configuration and control functions, as previously

described in relation to Figure 5. The gateway 14 also provides paths for external access to the system, specifically to the cellular wireless network, and external wired IP networks. The gateway is responsible for system integrity and security. The gateway contains tables identifying all devices in the system. These tables allow selective access between slave nodes. Closed User Groups (CUG) can be used to manage the selective access.

Now that several embodiments of the gateway system and method have been described in detail, it will be evident that it provides a number of advantages for interconnecting wireless ad-hoc networks, including the following:

(a) it implements a wireless local area network (wireless LAN) at significantly lower costs than comparable prior art wireless LANs;

(b) a variable-data-rate multi-mode wireless LAN can be implemented with the same architecture;

(c) it retains all of the advantages and benefits of wireless ad-hoc networks;

(d) it eliminates some of the disadvantages of ad-hoc networks, ie, two nodes can still communicate with each other even when they are not in range

(e) the system is transparent to the mobile nodes which can still join or leave the wireless ad-hoc networks a will;

(f) the gateway is able to perform protocol conversion such that the devices from different ad-hoc wireless network standards can still communicate with each other;

(g) it facilitates one common architecture to accommodate LAN functions for connections within the same piconet, between two different piconets, between two different piconets with different ad-hoc interface standards, between piconets and external wireless network, and between piconets and external wired network:

(h) the operational mode of the master node can be dynamically adapted to accommodate the requirements of coverage connectivity (unicast, multicast or broadcast), traffic load, QOS requirement and change of propagation environment;

(i) it retains the advantages of using a distributed antenna architecture whereby the coverage of a piconet is largely extended (eg 10 meters to 100 meters), and in addition the antenna configuration can adapt to traffic conditions and the propagation environment such that the coverage reliability and capacity are greatly improved;

(j) it automatically generates revenue for wireless operators, and the services of wireless operators are extended from outdoor to indoor;

(k) it provides services for multiple types of wireless user terminals as long as the user terminal is equipped with an ad-hoc device, ie, it provides connectivity to external wireless networks for phones with different wireless standards;

(l) the user can connect to the external network with a wireless ad-hoc device only, without a phone;

(m) it provides convenience to the user since the user needs to carry only one wireless handset with ad-hoc device mode capability;

(n) it allows the wireless operators to deploy earlier and at lower cost as well as extend coverage without extra BSs;

(o) it provides a cost-effective in-building distribution system for direct access to the subscribers for LMDS-type operators;

(p) the provision of wireless pathway between the gateway and the remote allows wireless operators to have easy installation and reconfiguration of the remote;

(q) it retains the advantages of a distributed antenna architecture whereby the antenna configuration can adapt to the environment such that the coverage reliability is greatly improved as well as the diversity gain.

Numerous variations and modification will suggest themselves to persons skilled in the electronic and telecommunications arts, in addition to those already described, without departing from the basic inventive concepts. All such variations and modifications are to be considered within the scope of the present invention, the nature of which is to be determined from the foregoing description and the appended claims.

THE CLAIMS DEFINING THE INVENTION

1. A gateway system for interconnecting wireless ad-hoc networks to a variety of external wired IP networks and/or external wireless networks as wireless local area networks (LANs), the gateway system comprising:

a gateway connected to one or more remotes of a distributed antenna architecture; and,

a master node connected to the gateway and configured to form a piconet with one or more slave nodes via the remotes, said master node being used to determine the synchronisation aspects of the piconet, and wherein the gateway routes the connections with the one or more remotes in an optimal manner within the same piconet or from one piconet to another.

2. A gateway system as defined in claim 1, wherein said master node is one of a plurality of master nodes, each master node being used to form at least one piconet.

3. A gateway system as defined in claim 2, wherein the gateway dynamically switches operation modes for the master nodes by reconfiguring the connectivity of the remotes within the distributed antenna architecture based on the traffic load and QOS requirements.

4. A gateway system as defined in claim 2, wherein the gateway performs admission control, service provisioning, connection set-up and tear-down, routing of traffic, as well as roaming functions.

5. A gateway system as defined in claim 4, wherein the gateway is provided with means for performing protocol conversion from one piconet to another if required.

6. A gateway system as defined in claim 4, wherein the gateway performs an interworking function, protocol conversion and protocol optimization from external wired IP networks or external wireless networks to internal wireless ad-hoc networks.

7. A gateway system as defined in claim 4, wherein the gateway is provided with means for performing traffic management for QOS provision for each connection.

8. A method of interconnecting wireless ad-hoc networks to a variety of external wired IP networks and/or external wireless networks as wireless local area networks (LANs), the method comprising:

providing a gateway connected to one or more remotes of a distributed antenna architecture;

providing a master node connected to the gateway and configuring the master node to form a piconet with one or more slave nodes;

using the master node to determine the synchronisation aspects of the piconet; and,

using the gateway to route the connections in an optimal manner from one piconet to another.

9. A method of interconnecting wireless ad-hoc networks as defined in claim 8, wherein a plurality of master nodes are provided, each master node being used to form at least one piconet.

10. A method of interconnecting wireless ad-hoc networks as defined in claim 9, further comprising using the gateway to dynamically switch operation modes for the master nodes by reconfiguring the connectivity of the remotes within the distributed antenna architecture based on the traffic load and QOS requirements.

11. A method of interconnecting wireless ad-hoc networks as defined in claim 9, further comprising using the gateway to perform protocol conversion from one piconet to another if required.

12. A gateway for interconnecting wireless ad-hoc networks as wireless local area networks (LANs), the gateway comprising:

a gateway controller adapted to communicate with a master node, said master node being configured to form a piconet with one or more slave nodes, the master node being connected to one or more remotes of a distributed antenna architecture connected to the gateway, wherein said gateway controller can route the connections in an optimal manner from one piconet to another.

13. A gateway for interconnecting wireless ad-hoc networks as defined in claim 12, wherein said gateway controller performs admission control, service provisioning, connection set-up and tear-down, routing of traffic, as well as roaming functions.

14. A gateway for interconnecting wireless ad-hoc networks as defined in claim 12, wherein the gateway controller includes a protocol optimisation unit for enhancing the performance of connections by optimising all protocol layers of the connections.

15. A gateway for interconnecting wireless ad-hoc networks as defined in claim 12, wherein the gateway controller includes a plurality of pathway interface modules for interfacing with various pathways connecting the gateway and the remotes.

16. A gateway for interconnecting wireless ad-hoc networks as defined in claim 14, wherein the protocol optimisation unit ensures that local connections are multiplexed into one physical connection between the gateway and an external wireless network

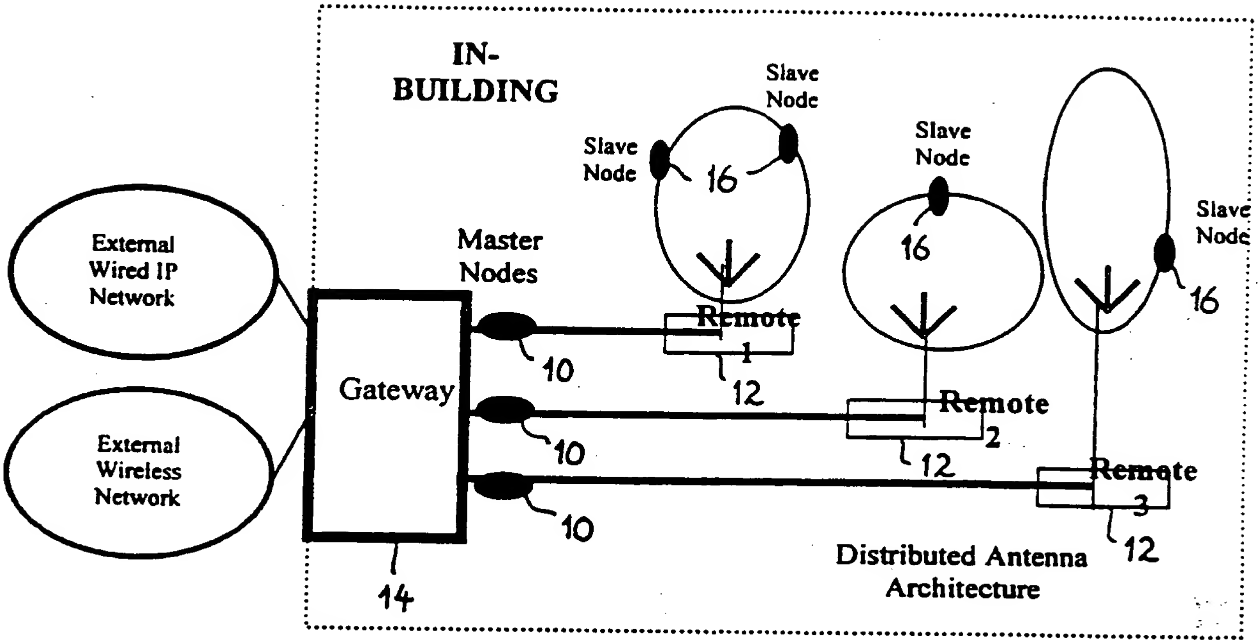

Figure 1

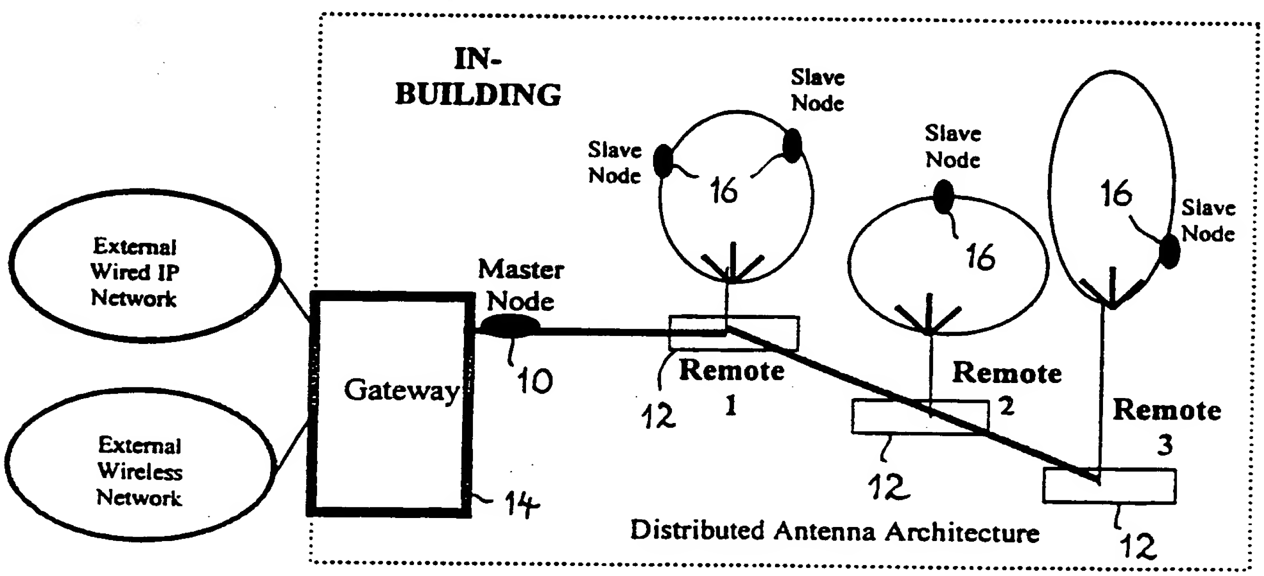

Figure 2

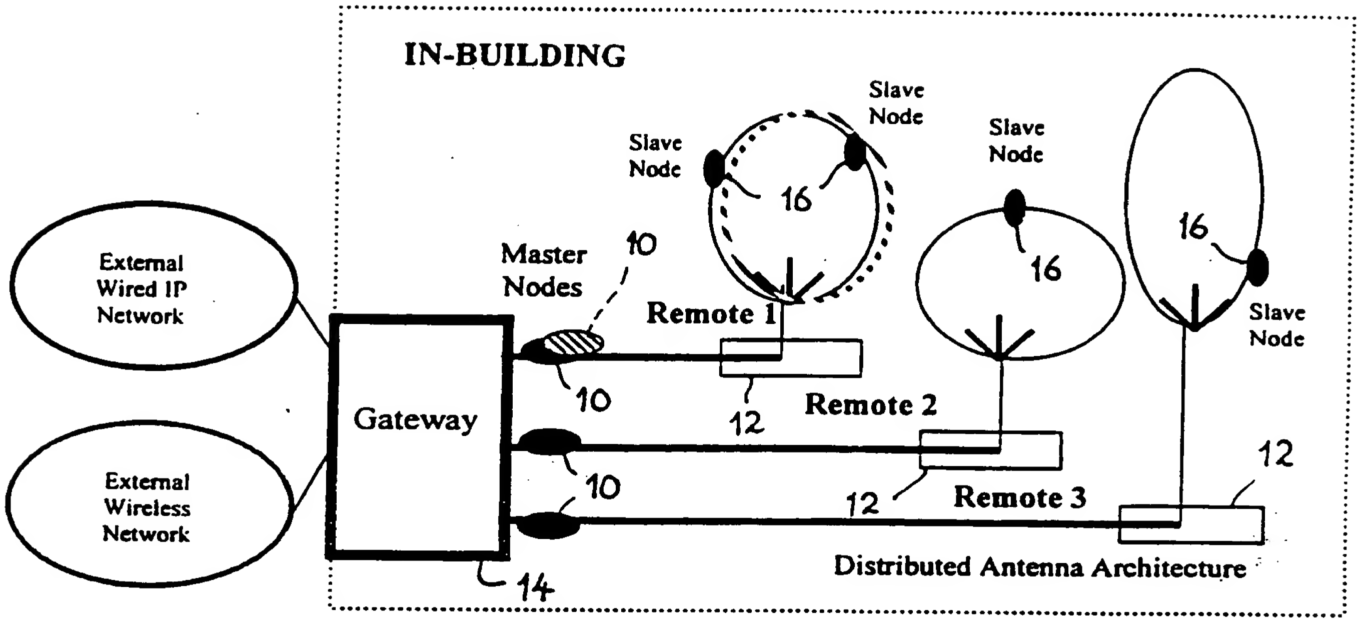

Figure 3

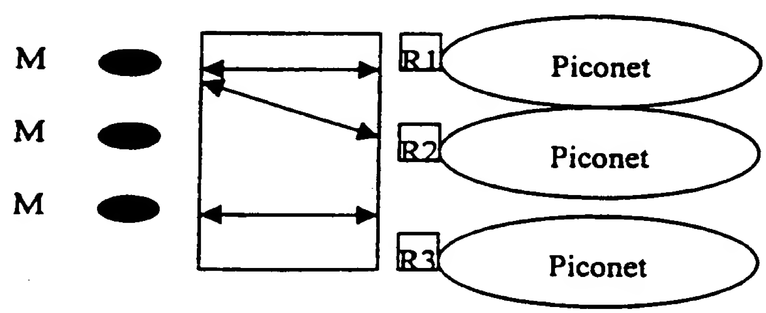

Figure 4a

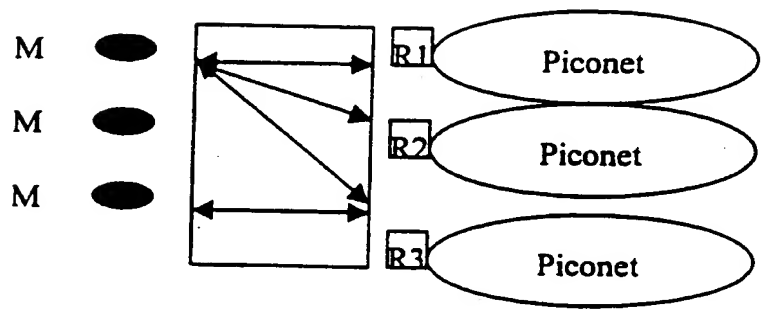

Figure 4b

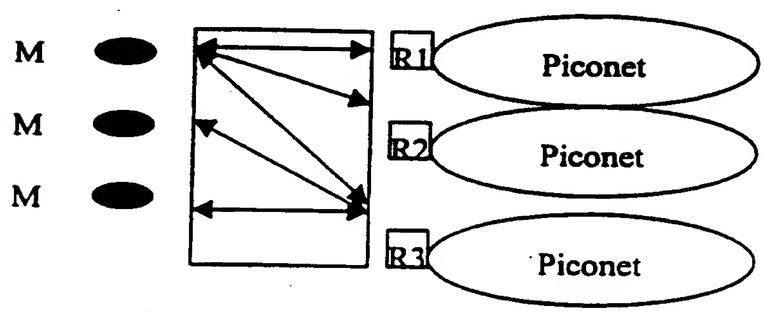

Figure 4c

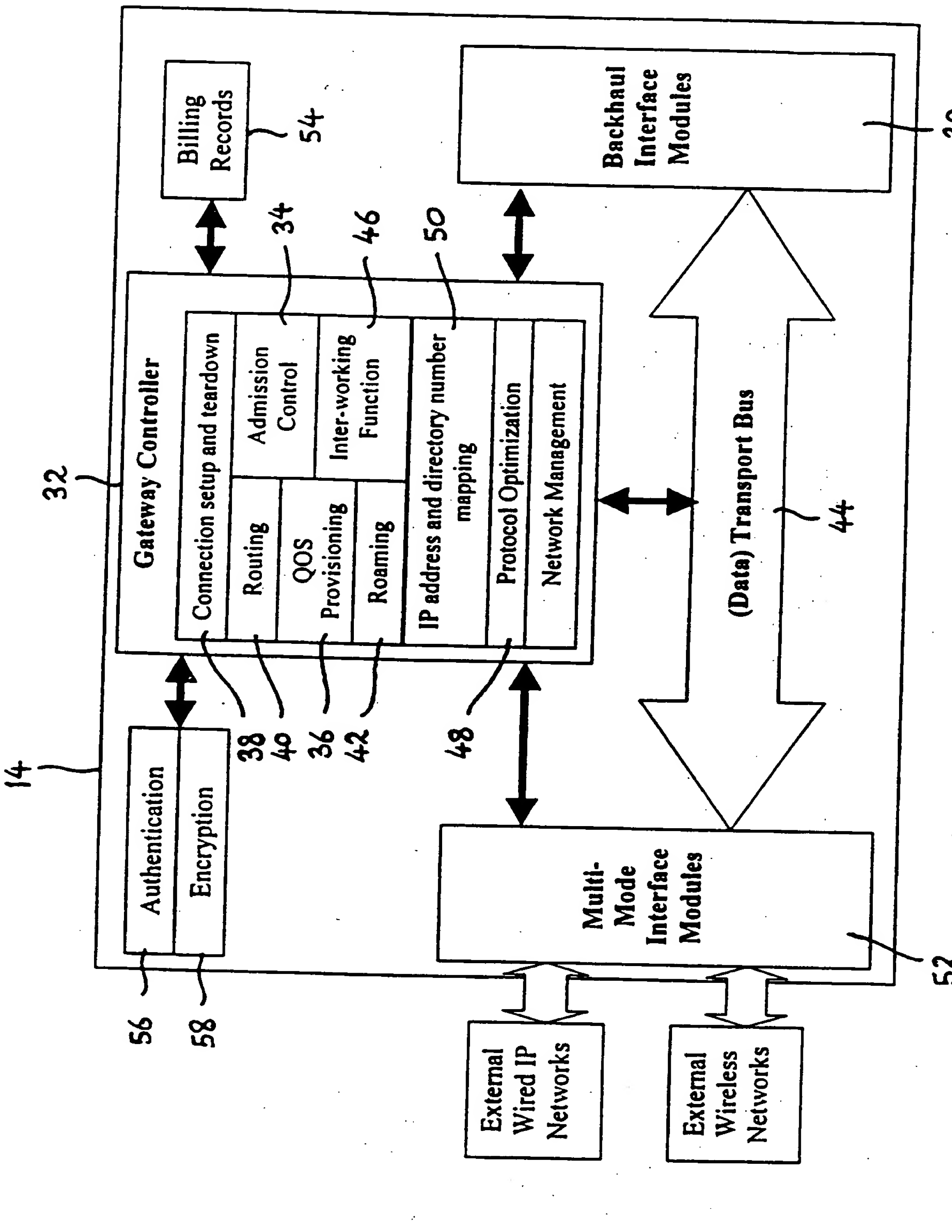
Billing Records
54
Backhaul Interface Modules
30
34
46
50
32
Gateway Controller
Connection setup and teardown
Admission Control
Inter-working Function
Routing
QOS Provisioning
Roaming
IP address and directory number mapping
Protocol Optimization
Network Management
(Data) Transport Bus
44
14
Authentication
Encryption
38
40
36
42
48
Multi-Mode Interface Modules
52
56
58
External Wired IP Networks
External Wireless Networks

Figure 5

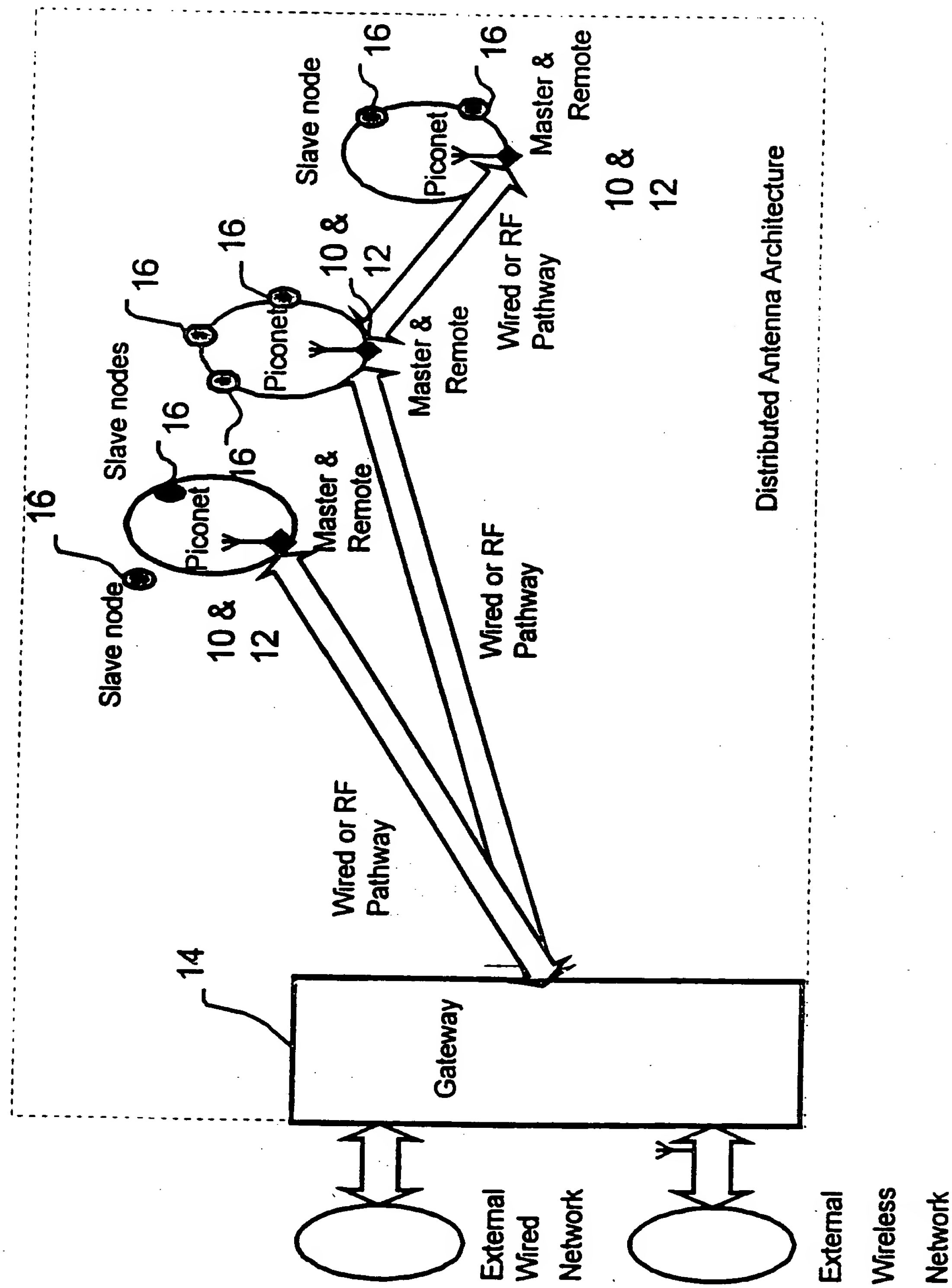
External
Wired
Network
External
Wireless
Network
Gateway
14
Wired or RF
Pathway
Wired or RF
Pathway
Wired or RF
Pathway
Slave node
16
Piconet
Master &
Remote
10 &
12
Slave nodes
16
16
Piconet
Master &
Remote
10 &
12
16
16
Slave node
16
16
Piconet
Master &
Remote
10 &
12
Distributed Antenna Architecture

Figure 6

INTERNATIONAL SEARCH REPORT

International application No.
PCT/AU 00/01413

A. CLASSIFICATION OF SUBJECT MATTER

Int Cl[7]: H04L 12/66, 12/46

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
WHOLE IPC

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
WHOLE IPC

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
WPAT: GATEWAY? AND (WIRELESS OR RADIO OR REMOTE) AND (NETWORK+ OR LAN?)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO 97/16007 A (TELECOM FINLAND OY et al) 1 May 1997 Page 1 line 2 - line 11; page 3 line 21 - page 10 line 8	1-16
P,A	EP 1011278 A (SYMBOL TECHNOLOGIES, INC.), 21 June 2000 Column 6 line 6 - column 7 line 32	1-16
P,A	EP 1035744 A (INTERNATIONAL BUSINESS MACHINES CORPORATION) 13 September 2000 Column 7 line 28 - column 25 line 41	1-16

[X] Further documents are listed in the continuation of Box C

[X] See patent family annex

* Special categories of cited documents:

"A" Document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
18 January 2001	6 FEBRUARY 2001

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/AU 00/01413

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
P,A	WO 00/60790 A (TELEFONAKTIE BOLAGET LM ERICSSON) 12 October 2000 Page 2 line 23 - page 3 line 12	1-16
P,A	EP 1049341 A (TELEFONAKTIEBOLAGET LM ERICSSON) 2 November 2000 Column 1 line 3 - column 3 line 23	1-16

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.
PCT/AU 00/01413

This Annex lists the known "A" publication level patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent Document Cited in Search Report		Patent Family Member					
WO	97/16007	AU	73025/96	FI	955810		
EP	1011278	AU	64470/99	CN	1272739	JP	2000183977
EP	1035744	CN	1267174	JP	2000270358		
WO	00/60790	NONE					
EP	1049341	WO	00/67500				

END OF ANNEX

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